DESCRIPTION

CONJUGATE FIBER WITH OPTICAL INTERFERENCE COLOR-GENERATING FUNCTION

Technical Field

The present invention relates to a conjugate fiber with an optical interference color-generating function. More specifically, it relates to a novel conjugate fiber with an optical interference color-generating function which can be used as an excellent brightening for a variety of fields of use, and which can be easily obtained as a high quality fine fiber having an optical interference color-generating function by treatment with an aqueous alkali solution or the like.

Background Art

Conjugate fibers having an optical interference color-generating function, composed of mutually independent polymer layers with different refractive indices forming an alternating laminate, produce interference coloring of wavelengths in the visible light region due to the reflection and interference effects of natural light. The color development has a brightness with a metallic gloss, and produces a pure and clear color (monochromatic) with a specific wavelength, while exhibiting an aesthetic quality entirely different from color formed by the light absorption of a dye or pigment. A concrete example of a conjugate fiber having an optical interference color-generating function is disclosed in International Patent Publication No. WO98/46815.

However, when it is attempted to increase the fineness of the conjugate fiber having an optical interference color-generating function as disclosed in the aforementioned international patent publication, peeling of the alternate laminated layers may occur, or even when peeling does not occur the spinning condition may be impaired due to

1

degradation of the polymer during spinning or the optical interference effect may be reduced by unevenness produced during the drawing step; this has constituted an impediment against development of the fiber to product applications which require improved aesthetic qualities, particularly for paints which must have a fine fiber size, cut fibers for such purposes as cosmetics and printing, and even for some filament uses.

Disclosure of the Invention

It is an object of the present invention to solve the aforementioned problems and provide a novel conjugate fiber which allows a fine conjugate fiber with an excellent optical interference color-generating function to be obtained by post-treatment, for development in commercial fields in which aesthetic qualities are demanded.

According to research by the present inventors, it was found that even with a small thickness of the alternating laminated section, if the structure includes a polymer covering the periphery then it is possible to inhibit peeling of the alternating laminated section and improve uniformity during the drawing step, and that if the covering polymer is later removed from the conjugate fiber, it is possible to obtain a stable fine conjugate fiber with an excellent optical interference color-generating function.

Specifically, a conjugate fiber with an excellent optical interference color-generating function according to the invention, which can achieve the object stated above, is characterized in that an alternating laminated section with a thickness of no greater than 10 μm, wherein alkali-insoluble polymer layers with different refractive indices are alternately laminated parallel to the long axis direction of the flat cross-section and the ratio (SP ratio) between the solubility parameter value of the higher refractive index polymer (SP1) and the solubility parameter value of the lower

2

refractive index polymer (SP2) is in the range of 0.8 ≤ SP1/SP2 ≤ 1.1, is covered with an alkali-soluble polymer with a thickness of 2.0 μm or greater.

Brief Description of the Drawings

Drawings (1) to (3) in Fig. 1 are schematic illustrations showing the lateral cross-sectional shape of conjugate fibers according to the invention.

Best Mode for Carrying Out the Invention

The cross-sectional structure of the conjugate fiber having an optical interference color-generating function according to the invention will now be explained with reference to the accompanying drawings. Drawings (1) to (3) in Fig. 1 are schematic representations of the cross-sectional shape of different conjugate fibers of the invention when cut at a right angle to the lengthwise direction, where each alternating laminated section comprising two different alkali-insoluble polymer layers has a flat cross-sectional shape, and the two different polymer layers are alternately laminated with multiple layers parallel to the long axis direction of the flat cross-section (the horizontal direction as seen in the drawing). Also, the circumference is surrounded by a covering layer composed of an alkali-soluble polymer, where (2) shows a form in which a separate alkali-insoluble protective layer is formed between them, and (3) shows a form in which the alternating laminated sections are simultaneously covered with an alkali-soluble polymer.

The thickness of each polymer layer in the alternating laminated section is preferably in the range of 0.02-0.5 μm. If the thickness is less than 0.02 μm or greater than 0.5 μm, it will be difficult to achieve the expected optical interference effect in a useful wavelength range. The thickness is more preferably in the range of 0.05-0.15 μm. A higher optical interference effect can be achieved if the

optical distance, i.e. the product of the layer thickness and refractive index of the two different components is equal. More preferably, twice the sum of the two optical distances is equal to the length of the desired color, in order to maximize the interference color.

The cross-sectional shape of the alternating laminate perpendicular to the fiber axis direction of the conjugate fiber of the invention is flat as shown in Fig. 1, and it has a long axis (horizontal direction in the drawing) and a short axis (vertical direction in the drawing). A large flatness (long axis/short axis) of the cross-section permits a larger effective area for optical interference, and is therefore the preferred fiber cross-section form. When the flatness of the fiber cross-section is at least 3.5, preferably at least 4.5 and especially at least 7, it is easier to align the flat axis sides of the fibers together in the parallel direction during use, and the optical interference color-generating function is improved. If the flatness is too large, however, the reeling property is notably reduced, and therefore it is preferably no greater than 15 and especially no greater than 12. In cases where the protective layer described below composed of an alkali-insoluble polymer covers the outer periphery of the flat cross-section, the protective layer section is included in calculating the flatness.

The number of different independent polymer layers laminated together in the alternating laminated section, in a cross-section of the fiber of the invention, is preferably 10-120 layers. The optical interference effect is reduced with less than 10 laminated layers. With more than 120 laminated layers, however, not only can no further increase in light reflection be expected, but the spinneret structure becomes complex and reeling is hampered, while it is not easy to satisfy the conditions described hereunder for the thickness of the alternating laminated section, such that the object of the invention becomes difficult to achieve.

4

As explained above, the cross-sectional shape of the alternating laminated section of the conjugate fiber of the invention is a flat shape with a plurality of polymer layers with different refractive indices alternately laminated, and in terms of the optical interference function, parallelism of the alternating laminated layers, i.e. uniformity of the optical distance of each layer in both the long axis and short axis directions of the flat cross-section, is extremely important for the reflection intensity and the monochromaticity (color generation clarity). In order to form a flat laminated structure with a large interfacial area, it is important to control the laminated layer-forming process in the complex spinneret flow channel, the Barus effect after discharge, interfacial tension and the like, in order to realize a uniform laminated layer thickness, and for this purpose it is essential to specify the ratio of the solubility parameter (SP value) between the layers of polymers with different refractive indices. That is, the ratio (SP ratio) between the solubility parameter value of the higher refractive index polymer (SP1) and the solubility parameter value of the lower refractive index polymer (SP2) must be in the range of $0.8 \leq SP1/SP2 \leq 1.1$, and especially in the range of $0.85 \leq SP1/SP2 \leq 1.05$. Such a polymer combination allows a uniform alternating laminated structure to be easily obtained since it reduces interfacial tension acting at the interface when the alternating laminated layer flow of the two different polymers is discharged from the spinneret. On the other hand, if the SP ratio is outside of the aforementioned range, the discharged polymer flow will tend to be rounded due to surface tension; moreover, shrinkage force acts to minimize the contact area at the interface between the two polymer laminated layers, and since the laminated structure includes multiple layers the shrinkage force is commensurately increased, resulting in rounding as the laminated layer surfaces become curved and making it impossible to obtain a

5

satisfactory flat shape. In addition, the Barus effect will become more prominent, whereby the polymer flow tends to swell after leaving the spinneret.

Examples of preferred combinations which satisfy the conditions described above include a combination of polymethyl methacrylate having an acid value of 3 or greater with polyethylene terephthalate copolymerized with a dibasic acid component having a metal sulfonate group at 0.3-10 mole percent per total dibasic acid component forming the polyester, a combination of an aliphatic polyamide with polyethylene naphthalate copolymerized with a dibasic acid component having a metal sulfonate group at 0.3-5 mole percent per total dibasic acid component forming the polyester, a combination of polymethyl methacrylate with an aromatic copolymer polyester copolymerized with a dibasic acid component or glycol component having a side chain alkyl group, at 5-30 mole percent per total repeating unit, a combination of polymethyl methacrylate with polyethylene terephthalate or polyethylene naphthalate copolymerized with 9,9-bis(parahydroxyethoxyphenyl)fluorene at 20-80 mole percent per total repeating unit, a combination of an aliphatic polyamide and polyethylene terephthalate or polyethylene naphthalate copolymerized with 9,9-bis(parahydroxyethoxyphenyl)fluorene at 20-80 mole percent per total repeating unit and a dibasic acid component having a metal sulfonate group at 0.3-10 mole percent per total dibasic acid component forming the polyester, a combination of polymethyl methacrylate and a polycarbonate comprising 2,2-bis(parahydroxyphenyl)propane as a dihydric phenol component, and a combination of polymethyl methacrylate and a polycarbonate comprising 9,9-bis(parahydroxyethoxyphenyl)fluorene and 2,2-bis(parahydroxyphenyl)propane (molar ratio: 20/80 - 80/20) as dihydric phenol components.

According to the invention, it is important for the thickness of the alternating laminated section to be no

6

greater than 10 μm and preferably 2-7 μm. If the thickness exceeds 10 μm, it is not possible to obtain a fine conjugate fiber with an optical interference color-generating function even if alkali treatment is performed, and the object of the invention therefore cannot be achieved.

If necessary, there may also be provided on the alternating laminated section a protective layer composed of an alkali-insoluble polymer, with a thickness of 0.1-3 μm and preferably 0.3-1.0 μm. If this thickness is smaller than 0.1 μm the effect of the protective layer will be minimal, and if it is greater than 3 μm it will be difficult to obtain a fine fiber with an optical interference color-generating function even if treatment with an aqueous alkali solution is carried out.

There are no particular restrictions on the polymer forming the protective layer so long as it is alkali-insoluble, but preferably it has a solubility parameter value (SP3) at the same level as the solubility parameter of the polymer composing both sides in the long axis direction of the alternating laminated section (the higher refractive index polymer or lower refractive index polymer), and specifically $0.8 \leq SP1/SP3 \leq 1.2$ and/or $0.8 \leq SP2/SP3 \leq 1.2$ is preferred. If it is the same as the higher melting point polymer of the alternating laminated polymers, the protective layer section is first formed of the polymer with the higher melting point which has the higher cooling solidification rate during melt spinning, so that deformation of the flat cross-sectional shape due to interfacial energy and the Barus effect can be suppressed, and the parallelism of the laminated structure can be maintained for an improved aesthetic quality.

The conjugate fiber with an optical interference color-generating function according to the invention must have the aforementioned flat lateral cross-sectional shape, and the alternating laminated section comprising multiple independent polymer layers with different refractive indices laminated

7

alternately parallel to the long axis direction of the flat
cross-section (if necessary comprising a protective layer)
must be covered with an alkali-soluble polymer having a
thickness of 2.0 µm or greater, preferably 2.0-10 µm and most
preferably 3.0-5.0 µm. By thus providing a covered layer made
of an alkali-soluble polymer surrounding the alternating
laminated section, it is possible to alleviate the polymer
flow distribution at the areas near the wall sides and the
interior which is received inside the final discharge opening
during melt spinning. As a result, even with an alternating
laminated section thickness of 10 µm or smaller, the shear
stress distribution received by the laminated section is
reduced and an alternating laminate is obtained with a more
uniform thickness of each of the layers from the outside to
the inside. Removal of the covering layer by alkali treatment
of the obtained conjugate fiber can easily yield a fine
conjugate fiber having an excellent optical interference
color-generating function.

If the thickness of the covering layer is too thin, i.e.
less than 2.0 µm, the single filament fineness of the fiber is
reduced, and because of its flat cross-section, the condition
in the spinning step is less favorable and problems are
created for handling during the post-treatment step. When a
covering layer made of an alkali-soluble polymer is provided
directly surrounding the alternating laminated section,
similar to when a protective layer made of an alkali-insoluble
polymer is formed as described above, it preferably has a
solubility parameter value (SP4) at the same level as the
solubility parameter of the polymer composing both sides in
the long axis direction of the alternating laminated section
(the higher refractive index polymer or lower refractive index
polymer). Specifically, $0.8 \leq SP1/SP4 \leq 1.2$ and/or $0.8 \leq
SP2/SP4 \leq 1.2$ is preferred.

According to the invention, alkali-insoluble and -soluble
polymers have a difference in alkali reduction rate of 10x or

8

greater. Specifically, this means that the alkali-soluble
polymer of the covering layer dissolves at a rate which is at
least 10 times faster than that of the alkali-insoluble
polymer composing the alternating laminated section during the
aqueous alkali solution treatment. If the dissolution rate
difference is less than 10-fold, the alternating laminated
section will also undergo corrosion during the aqueous alkali
solution treatment for removal of the covering layer, thus
producing laminated layer thickness irregularities due to
randomness or swelling in the laminated section, and reducing
the optical interference color-generating function.

Examples of preferred alkali-soluble polymers include
polylactic acid, polyethylene terephthalate or polybutylene
terephthalate copolymerized with polyethylene glycol, or
polyethylene terephthalate comprising polyethylene glycol
and/or an alkali metal alkylsulfonate, or polyethylene
terephthalate or polybutylene terephthalate copolymerized with
polyethylene glycol and/or a dibasic acid component having a
metal sulfonate group.

Polylactic acid is usually composed mainly of L-lactic
acid, but it may also contain other copolymer components such
as D-lactic acid in a range that does not exceed 40 wt%.
Polyethylene terephthalate or polybutylene terephthalate
copolymerized with polyethylene glycol preferably has a
polyethylene glycol copolymerization ratio of 30 wt% or
greater, in order to notably improve the alkali dissolution
rate. Polyethylene terephthalate or polybutylene
terephthalate comprising an alkali metal alkylsulfonate and/or
polyethylene glycol preferably comprises the former in a range
of 0.5-3.0 wt% and the latter in a range of 1.0-4.0 wt%, with
the average molecular weight of the latter polyethylene glycol
suitably in a range of 600-4000. Polyethylene terephthalate
or polybutylene terephthalate copolymerized with polyethylene
glycol and/or a dibasic acid component having a metal
sulfonate group may comprise the former in a range of 0.5-10.0

9

wt% and the latter in a range of 1.5-10 mole percent per total
dibasic acid component forming the polyester.

The conjugate fiber having an optical interference color-
generating function according to the invention preferably has
an elongation in the range of 10-60%, and especially in the
range of 20-40%. If the elongation is too large, the tension
load on the conjugate fiber may cause fiber deformation in the
step of producing a textile or cut fibers, thus tending to
reduce the process throughput. On the other hand, if the
elongation is too small it will be difficult for the conjugate
fiber to absorb the tension load, thus tending to increase
fluff and filament breakage. Even if the elongation is within
this range, certain types of polymers exhibit increase in the
birefringence (Δn) when the spun and solid-cooled conjugate
fiber is drawn, and since it is possible to achieve an overall
increase in the difference between refractive indices,
considering that the difference in refractive indices of the
two different polymers is the "difference in the refractive
indices of the polymers plus the difference in birefringence
of the fibers", the optical interference color-generating
function is increased.

Also, the conjugate fiber having an optical interference
color-generating function according to the invention
preferably has a heat shrinkage of no greater than 3% at 130-
150°C. If the heat shrinkage exceeds this range, fiber
shrinkage and other kinds of deformation that lower the
optical interference color-generating function will tend to
occur during the steps of producing various products such as
cloths, embroidering yarn and cut fibers for paper, paints,
inks, cosmetics and the like, during use in such products, and
during maintenance of such products by ironing, etc. For
example, when the fiber is used to produce a cloth, a
shrinkage of greater than 3% at 150°C will lead to shrinkage
of the fibers when ironed, tending to cause deformation of the
flat cross-section and reduce the optical interference color-

generating function. When the shrinkage is particularly high, for example in cases where absolutely no heat treatment has been carried out for structural fixation during the reeling step, the thickness of each layer of the alternating laminated structure is increased and alteration tends to occur in the color phase of the optical interference color generation itself. For use as a paint, for example, since drying and heat fixation are carried out at the same temperature in the painting step or printing step, a similar level of heat resistance is preferred from the standpoint of quality.

The conjugate fiber having an optical interference color-generating function according to the invention as described above may be produced by the following method, for example. Specifically, following the method described in International Patent Publication 98/46815, first alkali-insoluble polymers with different refractive indices, in a combination such that the ratio (SP ratio) between the solubility parameter value of the higher refractive index polymer (SP1) and the solubility parameter value of the lower refractive index polymer (SP2) is in the range of $0.8 \leq SP1/SP2 \leq 1.1$, are melted and discharged to form an alternating laminated structure, during which time the alternating laminated structure is covered with an alkali-soluble polymer having a higher alkali dissolution rate than either the higher refractive index polymer or the lower refractive index polymer, to obtain an undrawn fiber having a structure with the alternating laminated section covered with the covering layer. The single filament fineness of the undrawn fiber will differ depending on the draw ratio, and it may be as desired so long as the fineness of the conjugate fiber with the optical interference color-generating function obtained after aqueous alkali solution treatment is no greater than 4.0 dtex and preferably in the range of 0.2-3.0 dtex. The thickness of the covering layer may be as desired so long as the thickness of the covering layer after drawing is at least 2.0 μm.

Drawing may be carried out as necessary, while the conditions therefor are not particularly restricted and may be conventionally known drawing conditions for undrawn fibers. For example, drawing may be carried out at any temperature near the glass transition temperature (Tg ±15°C) of the polymer with the highest glass transition temperature, which still allows orientation of the polymer molecule chains. The temperature in this case is the temperature of the heating medium, such as the heating plate or heating roller. The draw ratio may be set as appropriate depending on the degree of strength and elongation property or thermal shrinkage property to be imparted to the finally obtained drawn fiber, but in most cases drawing may be to a maximum draw ratio of 0.70-0.95. In order to improve the heat resistance, including the thermal shrinkage property, the drawing may be followed by heat treatment.

The conjugate fiber having an optical interference color-generating function according to the invention, which has been drawn and heat treated as necessary, may be used directly as filaments, or it may be cut for use as staple fibers. When staple fibers are produced they may be cut to a length suited for the purpose, and for application in such fields as paper, paints, inks, cosmetics and coatings, from the standpoint of handling properties during use and the aesthetic quality of the final product, they are preferably cut so that the fiber length in the fiber axis direction is longer than the short axis length of the fiber cross-section, ignoring the alkali-soluble polymer section. The upper limit for the length will usually be about 50 mm, and particularly for uses involving fine dispersion such as cosmetics and paints, it is preferably no greater than 1 mm. A shorter length is preferred so long as it is greater than the long axis length of the laminated section, and especially a length of a few tens to a few hundred μm is preferred.

When the conjugate fiber of the invention is to be used

12

directly as filaments, for example, it may be employed to form a textile with a desired textile design, and then treated with an aqueous alkali solution to remove the alkali-soluble polymer and obtain a textile material composed of the fine conjugate fiber having an optical interference function.

On the other hand, when it is to be used as staple fibers, for example, they may be treated with an aqueous alkali solution beforehand to remove the alkali-soluble polymer, and then utilized in various ways as fine conjugate staple fibers having an optical interference function. Also, the conjugate fiber of the invention may be treated with an aqueous alkali solution while in skein form to remove the alkali-soluble polymer at a stage prior to producing staple fibers, and then cut afterwards.

Examples

The present invention will now be explained in greater detail through examples. The polymer solubility parameter value (SP value) and the dimensions of the fiber cross-section mentioned throughout the examples were measured by the following methods.

<SP value and SP ratio>

The SP value is the value represented by the square root of the cohesive energy density (Ec). The Ec of a polymer is determined by immersing the polymer in various solvents, and recording the Ec of the polymer as the Ec in the solvent with the maximum swelling pressure. The SP values for different polymers determined in this manner are listed in "PROPERTIES OF POLYMERS" 3rd Edition (ELSEVIER), p.792. For a polymer with an unknown Ec, it may be calculated from the chemical structure of the polymer. That is, it may be determined as the sum of the Ec values for each substituent in the polymer. The Ec values of different substituents are listed on page 192 of the aforementioned reference. The SP ratio of the alternating laminated section may also be calculated by the

13

following formula.

SP ratio = SP value of high refractive index polymer (SP1)/SP value of low refractive index polymer (SP2)

<Fiber cross-section measurement>

The sample fiber is affixed to a flat silicon plate and beam capsule, and embedded in an epoxy resin. Next, an ULTRACUT-S microtome is used for cutting in the direction perpendicular to the fiber axis to create ultrathin samples with thicknesses of 50-100 nm, which are mounted on a grid. After two hours of vapor treatment with 2% osmium tetraoxide at no higher than 60°C, an LEM-2000 transmission electron microscope is used for photography (20,000x) at an acceleration voltage of 100 kV. The mean thickness of each layer of the laminated structure section and the covering layer thickness were measured from the obtained photograph.

<Optical interference color-generating wavelength and intensity>

A sample fiber (multifilament yarn) was wound on a black board at a winding density of 40 strands/cm and a winding tension of 0.265 cN/dtex (0.3 g/de), and colorimetry was performed using a Macbeth ColorEye 3100 (CE-3100) spectrophotometer, with a D65 light source. The measurement aperture was 25 mmφ for the large aperture, and the peak wavelength and reflection intensity were measured under conditions including an ultraviolet light source. For the reflection intensity, the difference in reflection intensity at baseline and peak wavelength was determined as the net reflection intensity.

Examples 1-7 and Comparative Examples 1-2

The high refractive index polymer (Polymer 1) and the low refractive index polymer (Polymer 2) listed in Table 1 were melt spun in such a manner as to form a structure with 21 alternating laminated sections and an alkali-soluble polymer 3 covering the periphery thereof, and the structure was wound up at the speed shown in Table 1. The obtained undrawn fiber was

14

then drawn at the draw ratio listed in Table 1 to obtain a conjugate fiber having an optical interference color-generating function, with the cross-sectional shape shown in Fig. 1(1). The evaluation results are shown in Table 2.

Table 1

	High refractive index polymer		Low refractive index polymer		SP Ratio SP1/SP2	Covering layer		SP ratio SPn/SP4	Spinning speed m/min.	Draw ratio	Protective layer SP3
	Polymer type	SP1	Polymer type	SP2		Polymer type	SP4				
Example 1	Copolymer PEN1	19.1	NY6	22.5	0.85	PEGPBT	20.4	0.94(1/4)	1200	2.0	-
Example 2	Copolymer PET2	21.06	PMMA	18.3	1.15	Polylactic acid	19.9	1.06(1/4)	2000	-	-
Example 3	Copolymer PEN2	19.46	PMMA	18.3	1.06	Polylactic acid	19.9	0.98(1/4)	2000	-	-
Example 4	Copolymer PC	21.45	PMMA	18.3	1.17	Polylactic acid	19.9	1.08(1/4)	2000	-	-
Example 5	Copolymer PET1	21.5	NY6	22.5	0.96	Copolymer PET	20.9	1.03(1/4)	2000	1.5	-
Example 6	Copolymer PET3	21.06	NY6	22.5	0.94	Copolymer PET	20.9	1.01(1/4)	2000	2.0	-
Example 7	PC	20.3	PMMA	18.3	1.11	Polylactic acid	19.9	0.92(2/4)	3000	-	-
Example 8	PC	20.3	PMMA	18.3	0.90	Polylactic acid	19.9	1.02(3/4)	3000	-	PC(20.3)
Comp.Ex. 1	PEN	18.9	PET	21.5	1.03	PEGPET	21.3	0.93(1/4)	1000	3.0	-
Comp.Ex. 2	PS	17.4	NY6	22.2	0.77	Polylactic acid	19.9	0.87(1/4)	2000	-	-

16

The abbreviations for the polymers in Table 1 are as follows.

PET: Polyethylene terephthalate

Copolymer PET1: Copolymer polyethylene terephthalate with 0.8 mole percent 5-sodiumsulfoisophthalic acid component

Copolymer PET2: Copolymer polyethylene terephthalate with 70 mole percent 9,9-bis(parahydroxyethoxyphenyl)fluorene (BPEF)

Copolymer PET3: Copolymer polyethylene terephthalate with 70 mole percent 9,9-bis(parahydroxyethoxyphenyl)fluorene (BPEF) and 0.8 mole percent 5-sodiumsulfoisophthalic acid component

PEN: Polyethylene-2,6-naphthalate

Copolymer PEN1: Copolymer polyethylene-2,6-naphthalate with 1.5 mole percent 5-sodiumsulfoisophthalic acid component

Copolymer PEN2: Copolymer polyethylene-2,6-naphthalate with 70 mole percent BPEF

PC: Polycarbonate

Copolymer PC: Copolymer polycarbonate with 70 mole percent 9,9-bis(4-hydroxyethoxy-3-methylphenyl)fluorene (BCF)

PMMA: Polymethyl methacrylate

PS: Polystyrene

NY6: Nylon-6

PEGPBT: Copolymer polybutylene terephthalate with 50 wt% (5.2 mole percent) polyethylene glycol of average molecular weight of 4000

PEGPET: Copolymer polyethylene terephthalate with 10 wt% polyethylene glycol of average molecular weight of 4000

Copolymer PET: Copolymer polyethylene terephthalate with 3 wt% polyethylene glycol of average molecular weight of 4000 and 6 mole percent 5-sodiumsulfoisophthalic acid

Table 2

	Alternating laminated section				Covering layer	Conjugate fiber		Fiber properties after alkali treatment		
	Flatness ratio	Polymer 1 thickness nm	Polymer 2 thickness nm	Thickness μm	Covering layer thickness μm	Flatness ratio	Total thickness μm	Laminated section	Interference wavelength nm	Coloring intensity %
Example 1	6.8	80	85	1.7	5	4.5	11.7	no corrosion	529	16
Example 2	5.3	95	110	2.3	4	4.3	10.3	no corrosion	636	18
Example 3	7.4	70	73	1.5	3	5.2	7.5	no corrosion	456	20
Example 4	6.1	75	80	1.6	2	4.5	5.6	no corrosion	481	19
Example 5	8.5	72	78	1.6	3	4.8	7.6	no corrosion	466	10
Example 6	7.8	78	80	1.7	5	4.2	11.7	no corrosion	486	20
Example 7	6.2	76	80	1.4	2	4.2	5.6	no corrosion	502	17
Example 8	5.2	90	85	1.8	5 (0.7*)	4.2	13.2	no corrosion	539	21
Comp.Ex. 1	8.9	70	61	1.4	3	4.8	7.4	some corrosion	428	7
Comp.Ex. 2	1.5	120	150	2.8	5	4.8	12.8	no corrosion	420	3

* Protective layer thickness = 0.7 μm (Example 8)

18

For Example 1, polyethylene-2,6-naphthalate copolymerized with 1.5 mole percent of 5-sodiumsulfoisophthalic acid, nylon-6, and polybutylene terephthalate copolymerized with 2.5 mole percent of polyethylene glycol of average molecular weight of 4000, were each melted at 290°C, 270°C and 230°C, and after weighing were introduced into a spinning pack and spun at 1200 m/min. The obtained undrawn filament was drawn at the draw ratio of 2 with a preheating temperature of 60°C, and then heat set at 150°C and wound up. The obtained conjugate fiber showed no damage to the alternating laminated section even after alkali treatment, and the interference reflection light of the obtained conjugate fiber was a clear green color. For Examples 2 and 3, polyethylene terephthalate (PET) or polyethylene-2,6-naphthalate (PEN) copolymerized with 70 mole percent 9,9-bis(parahydroxyethoxyphenyl)fluorene (BPEF), polymethyl methacrylate (PMMA), and polylactic acid were each melted at 300°C, 255°C and 230°C, and after weighing were introduced into a spinning pack and spun at 2000 m/min. The obtained conjugate fibers all produced fine fibers and cut fibers with excellent color-generating performance. For Example 4, polycarbonate copolymerized with 70 mole percent 9,9-bis(4-hydroxyethoxy-3-methylphenyl)fluorene (BCF) was used for spinning in the same manner as Example 2, but with a melting temperature of 300°C. The obtained conjugate fiber had a clear color and strong reflection intensity. Also, the alternating laminated section suffered no damage in the aqueous alkali solution treatment step. For Example 5, PET copolymerized with 0.8 mole percent 5-sodiumsulfoisophthalic acid, nylon-6, and PET copolymerized with PEG for alkali solubility and 5-sodiumsulfoisophthalic acid, were spun at melting temperatures of 290°C, 270°C and 290°C, respectively, and wound up at a speed of 2000 m/min. The obtained unstretched filament was preheated at 80°C, drawn at the draw ratio of 1.5 and heat set at 180°C. The reflection intensity

19

was somewhat low due to a smaller refractive index difference compared to the other combinations, but the obtained conjugate fiber had excellent heat resistance and strength. For Example 6, PET copolymerized with 70 mole percent 9,9-bis(parahydroxyethoxyphenyl)fluorene (BPEF) and 0.8 mole percent 5-sodiumsulfoisophthalic acid, nylon-6, and PET copolymerized with PEG for alkali solubility and 5-sodiumsulfoisophthalic acid, were spun at melting temperatures of 290°C, 270°C and 290°C, respectively, and wound up at a speed of 2000 m/min. The obtained undrawn filament was preheated at 80°C, drawn at the draw ratio of 2.0 and heat set at 180°C. The obtained conjugate fiber had excellent reflection intensity, heat resistance and solvent resistance. For Example 7, polycarbonate (PC) and PMMA were melted at 290°C and 255°C while polylactic acid was melted at 230°C, and they were weighed, introduced into a spinning pack and spun at 3000 m/min. The obtained conjugate fiber had a high degree of flatness and exhibited a strong, clear color. For Example 8, there was formed a cross-section provided with a PC intermediate protective layer formed surrounding the PMMA/PC laminated section (Fig. 1(2)). It was particularly excellent from the standpoint of heat resistance. For Comparative Example 1, however, PEN and PET, which have comparable SP values and are expected to have excellent uniform laminate-forming ability, and PET copolymerized with 10 wt% PEG, were melted at 310°C, 300°C and 290°C, respectively, introduced into a spinning pack and spun at 1000 m/min. The spun fiber was drawn at the draw ratio of 3 with preheating at 80°C, and heat set at 180°C. Since the dissolution rate of the covering layer in the aqueous alkali solution was at least 3 times (no greater than 10 times) that of the polymers composing the alternating laminated section, alkali corrosion was observed in the alternating laminated section after treatment and the reflection intensity was notably reduced. For Comparative Example 2, nylon-6, polystyrene and polylactic acid were

melted at 270°C, 270°C and 230°C, respectively, introduced into a spinning pack and spun at 2000 m/min. Because the SP ratio for the polymers of the alternating laminated section was outside of the range of the invention, the layer thickness of the alternating laminated section was large, the optical interference color-generating function was insufficient and the reflection intensity was low, such that a clear color satisfying the object of the invention could not be achieved.

Industrial Applicability

The conjugate fiber with an optical interference color-generating function according to the invention has satisfactory processing stability for reeling, and thus exhibits an excellent optical interference color-generating function even with a small alternating laminated structure thickness, while it is possible to easily obtain a fine fiber with an optical interference function either using the fiber directly as filaments, or by removing the covering layer after first cutting into staple fibers. Particularly when cut fibers of short lengths are produced, not only is the dispersibility suitable for utilization in paints, inks, coating agents, cosmetics and the like, but the surface smoothness of resulting products is also improved and the optical interference color-generating function and aesthetic quality are satisfactory.